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Sand Fences in the Coastal Zone: Intended and Unintended Effects

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Abstract Sand-trapping fences modify the character of the coastal landscape and change its spatial structure, image, and meaning. This paper examines the relationship between these changes and fence usage at the municipal level, where most decisions about fence deployment are made. Use of fences in 29 municipalities on the developed coast of New Jersey is examined over a 6-year period. Interviews with municipal officers indicate that wooden slat sand-trapping fences are used primarily to build dunes to provide protection against wave uprush and flooding, but they are also used to control pedestrian traffic and demarcate territory. These uses result in changes in landforms and habitats. An aerial video inventory of fences taken in 2002 indicates that 82% of the shoreline had fences and 72% had dunes. Single and double straight fence rows are the most commonly used. Fences are often built to accomplish a specific primary purpose, but they can cause many different and often unanticipated changes to the landscape. The effects of a sand fence change through time as the initial structure traps sand, creates a dune that is colonized by vegetation, and becomes integrated into the environment by increasing topographic variability and aesthetic and habitat value. Sand fences can be made more compatible with natural processes by not placing them in locations where sources of wind blown sand are restricted or in unnatural shore perpendicular orientations. Symbolic fences are less expensive, are easy to replace when damaged, are less visually intrusive, and can be used for controlling pedestrian access.

Keywords Beach · Dune · Landscape · Sand fence · Wind-blown sand

Introduction

Fences, walls and their vegetative equivalents (windbreaks and shelterbelts) are human-created physical boundaries that differentiate spaces and their purposes and constrain natural physical and biotic processes and human actions. These boundaries, hereafter termed fences, may be constructed to many designs using many different construction materials, including concrete, iron, wood, wire, plastic, stone, sod, and vegetation (Martin 1888; Hewes 1981; Pickard 2005, 2007; Raitz 1995; VerCauteren and others 2006). They can extend for tens to thousands of kilometers regionally (Hewes 1981; Price 1993) and over a million kilometers on a national scale (Hewes and Jung 1981; Pickard 2007). The presence of fences influences the spatial structure and image of a landscape and imparts historical meaning, making fences a manifestation of culture and index of landscape character (Eley and Northon 2003; Hart and Mather 1957; Pickard 2007; Price 1993). Fences can be evaluated economically, politically, or in terms of sustainability of resources (Centner 2000). They are often built to accomplish a specific purpose, but they can cause many alterations to a landscape. Like many other human structures, little thought is often given to designing or constructing fences to address the unanticipated effects they create.

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Fences are often used to control wind-blown sand in the coastal zone. One of the most ubiquitous fence types is the permeable wooden slat fence that is also used to prevent inundation by snow (Dong and others 2004; Skidmore and others 1972; Zaghloul 1997). Other common fencing materials used at the coast are commercially produced plastic mesh or saplings and branches placed close together in a vertical array. These fences not only reduce wind speed, but also trap sand and create dunes that provide protection against flooding, overwash, and sand inundation, often in locations where they would not occur under natural conditions. Use of sand-trapping fences, hereafter termed sand fences, is documented as early as the 15th century in Europe (Cordshagen 1964; van der Laan and others 1997), and they are now deployed all over the world (Bouaziz and others 2003; Gómez-Pina and others 2002; Hotta and others 1987, 1991). Sand fences are important human adjustments affecting the morphology and vegetation on sandy coasts because they are one of the few structures permitted seaward of the dune crest, they are inexpensive and easy to emplace, and they are usually deployed on the highly dynamic backshore (Nordstrom 2000). They are also useful in controlling hazards of wind-blown sands well landward of the beach (Sherman and Nordstrom 1994). Sand fences have not only transformed the morphology of the shore, they are now an accepted part of the coastal image.

The geomorphic and engineering purposes of sand fences are well studied (e.g., Gares 1990; Hotta and others 1987, 1991; Mendelssohn and others 1991; Miller and others 2001; Snyder and Pinet 1981). Most investigators evaluate the way fences can be used as barriers to sediment transport and as a means of building dunes as protection structures, rather than the way they influence human use and create environments for biota. Limited information exists about the significance of sand fences as instruments of change in landscape character.

Our objective is to analyze the effects of sand fences in modifying the character of the coastal landscape and to examine the relationship between these effects and fence usage at the municipal level, where most decisions about fence deployment are made. Steps include (1) identifying the many purposes and effects of fences, including those not solely designed for use in the coastal zone; (2) conducting an inventory of sand fence characteristics on a representative developed coast; (3) identifying how these characteristics change over several years; (4) identifying reasons why municipal managers install fences and select the locations and configurations for fence construction; (5) identifying the unanticipated outcomes of fence construction; and (6) suggesting alternative methods for emplacing fences on beaches and dunes. New Jersey is selected as the study area because it is one of the most intensively developed coastal states in the United States, and it has been identified as a template by which developing coasts can be evaluated (Nordstrom 1994). Dunes are municipally managed even though portions of the shoreline with dunes are privately owned. Managers are free to select their own fence configurations and locations and numbers of fence rows following a general municipal practice.

Purposes and Effects of Fences

Fences are commonly used to control the flows of air, water, sediments, people, and animals (Table 1). This barrier effect can allow some elements to pass it, or it can stop or even repel flows or activity, causing accumulation or dispersion of the controlled item. The barrier effect can be due to the structure itself or to a change in landform or vegetation induced by the structure, which can persist

Table 1 Purposes and effects of fences in the landscape: purposes and effects are not mutually exclusive

Purpose
Control processes (impede, reduce or redirect flows of wind, water or sediment)
Control sediment
Retain sedimentary resource within an area
Prevent inundation outside area
Cause accretion (build landforms)
Control animal access
Keep domesticated animals within managed properties.
Keep wild animals out of populated areas, agricultural lands, and pastures
Keep wild animals from transportation corridors
Control human access
Crowd control
Prevent human access to territory owned by another owner or jurisdiction
Prevent human access to vulnerable habitat or valued public resources
Provide safety barriers from hazards or self-inflicted damage
Create privacy
Demarcate territory
Differentiate land use
Change landscape image
Dispose of unwanted items
Effect
Habitat change
Physical effect of fence itself
Effect of sediment accretion (new landform)
Economic
Psychological
Political
Cultural icon
Aesthetic

even when the fence is buried or obscured. Land cover and land use can evolve on different trajectories on both sides of the fence or the resulting landform that is created from it as a primary or secondary effect (Minnich and Bahre 1995). Many physically based studies of fences for controlling wind effects exist (e.g., Bates 1911; Burke 1998; Caborn 1965; Grant and Nickling 1998; Sturrock 1988; Tinus 1976; Wang and Takle 1995; Wilson 1997), with emphasis on soil loss and suspension of particulates. The landforms created in the process are often of lesser interest.

The literature on use of fences to control animal access to nesting and feeding sites or prevent predation or interaction with humans is vast (Anthony 2007; Cole and others 2007; Dodd and others 2004; Gallacher and Hill 2008; Jackson and others 2005; Matsumasa and Murai 2005; Melvin and others 1991, 1992; Miller and others 2001; Moseby and Read 2006; Patterson 1977; Rimmer and Deblinger 1990; Spooner and Biggs 2008). Control of human access is often motivated by social, political, or economic reasons. Fences may also be used to keep people out of valued public resources or sensitive or hazardous environments (Holloway 2002). Fences can have important psychological as well as physical effects (Cohen 2006; Edmonds 1979; Lagerquist 2004; Litz 2000; Schnell and Mishal 2008). Control of access for people or animals can be considered in their best interests when the barrier is designed for safety (Bateman and others 2007; Dodd and others 2004; Pelletier 2007) or against their interests when the barrier unnecessarily restricts their freedom or access to resources that affect their livelihood (Moseby and Read 2006; Olsson and others 2008).

Fences may be deployed to differentiate land uses, without regard to their effect on flows of air or water or movement of fauna, such as when managers wish to make a statement of ownership. Fences may also be constructed as evocative symbols to change the landscape image (Harrod 1991; Price 1993). Once in the landscape, fences can become cultural icons and targeted for preservation or restoration because of their heritage value (Pickard 2005, 2007), and they can become objects of aesthetic interest and take on many meanings in artistic portrayals as objects of beauty, nostalgia, or social comment (Doherty 2001; Gomez 2003).

Fences may be created by disposing of unwanted materials, such as where boulders are placed to the side of a cleared field. These disposal fences provide dramatic evidence of the way unanticipated effects of fence construction can transform the landscape and define its character. Most of the issues related to fences reported in the literature are applicable in some way to sand fences at the coast. These issues are readily illustrated in the ways fences are deployed on the ocean shore of New Jersey.

Sand Fences and Dune Building in New Jersey

The 205-km-long ocean shore of New Jersey (Fig. 1) consists of sandy barrier spits and barrier islands and low headlands composed of unconsolidated sediment. Before the mid 19th century, multiple dune ridges were common in portions of several barrier islands, and large portions of most of the islands were characterized by isolated hummocky dunes. Human modifications included grading dunes and destroying natural vegetation to facilitate construction of buildings and roads. Much of the ocean shore was developed in residential properties by 1962, when a midlatitude cyclone in March damaged thousands of residences and destroyed nearly all of the remaining dunes along entire barrier islands (USACOE 1962, 1963). Restoration of dunes using artificial fill, sand fences and vegetation plantings was one of the many poststorm reconstruction activities (Nordstrom and Mauriello 2001).

A renewed state focus on building dunes followed damaging storms in 1977–1978 and development of the New Jersey Shore Protection Master Plan in 1981 that encouraged use of nonstructural approaches to shore protection (NJDEP 1984). The state then adopted a formal Hazard Mitigation Plan recommending dune creation and enhancement as a

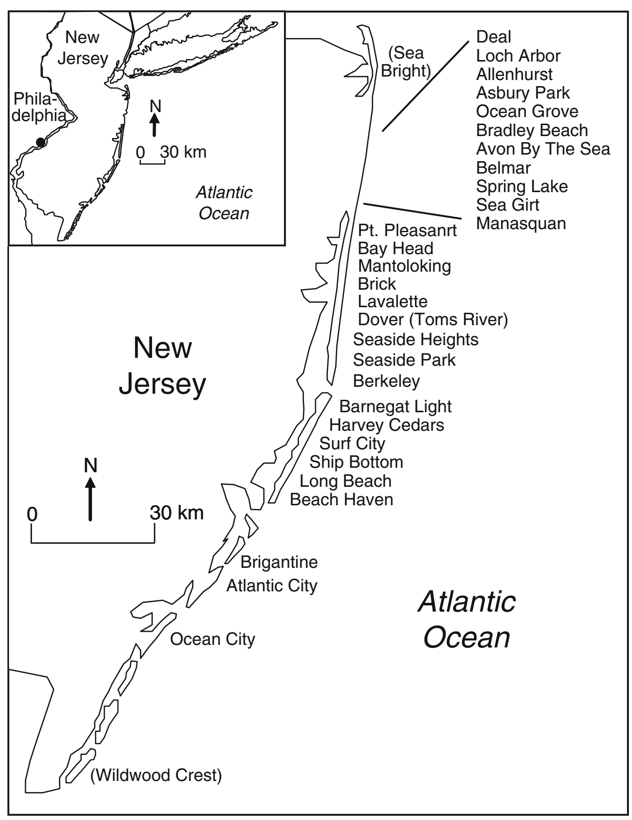

Fig. 1 New Jersey coastal municipalities where sand fences were evaluated

primary hazard mitigation effort. Federal funds were passed through to municipalities to make vegetation and sand fence materials available. The state required municipalities to agree to dune building as a condition of receiving aid to rebuild damaged structures, resulting in construction of new dunes in municipalities that accepted this funding (Nordstrom and Mauriello 2001). Legislative amendments to the State Coastal Area Facilities Review Act in 1993/1994 allow for construction of sand trapping fences but prohibit direct disturbance to dunes that would increase their mobility or reduce their dimensions, including removal of existing sand fences or pedestrian trampling of the vegetation. Most municipalities now have regulations that restrict access to dunes except along designated paths to the beach. The state regulation against removing fences helped curtail a former practice of creating dunes in the fall to provide protection against winter storms and flattening the structures prior to the summer tourist season.

The fences employed throughout the state are similar to fences used to build dunes in other parts of the United States (Savage and Woodhouse 1968; CERC 1984; Mendelssohn and others 1991) and are 1.2-m high, with 35-mm-wide wooden slats joined together by horizontal strands of wire strung along vertical wood or commercially produced iron poles. The fences have a porosity of about 50% initially, although they often weather to a porosity closer to 65%. Some municipalities provide fence materials for use on private properties, but fence materials are so inexpensive that residents do not need this incentive to use them.

Dunes in areas where beaches are narrow are usually a single ridge, with vegetation characterized by species commonly found on the active beach and seaward portions of natural dunes. American beach grass (*Ammophila breviligulata*) usually dominates because it is planted. Dunes that have crests high enough to reduce the impact of wind, salt spray, and blowing sand may have a more complete environmental gradient perpendicular to the shore, with shrubs such as bayberry (*Myrica pennsylvanica*) and rugosa rose (*Rosa rugosa*) landward of the crest. Many beaches in New Jersey are artificially nourished (Nordstrom and Mauriello 2001). Where there is ample space on the backshores of these beaches, municipalities often progressively place sand fences on the seaward side of the dune to encourage horizontal growth rather than upward growth that would restrict views of the sea. This practice creates small dune fields with multiple low ridges.

Methods

The inventory of sand fence characteristics was conducted to identify the amount of shoreline with or without fences or dunes, fence configurations (including straight or zigzag, alongshore, diagonal or perpendicular to shore), number and location of fences, and relationship of fences to the seaward-most cultural feature (usually a boardwalk or bulkhead). The inventory was conducted using an unrectified oblique video of the ocean shore taken from a light airplane. Inexpensive video records provide managers with massive amounts of data over large areas within a limited time and budget (Leatherman and others 1995). The video was taken during a morning in August 2002 when the sun was offshore and was originally used for a different purpose (Mitteager and others 2006). A total of 29 municipalities representing portions of all four oceanside New Jersey counties along a 90.7-km length of shoreline were evaluated using the video record.

The beginning and end points of each shoreline segment with a specific fence characteristic were marked relative to human features, which were then located on a map to measure length. Dunes were identified using vegetation cover and difference in height observable by the shadow they cast. Fenced segments that had no vegetation cover or were not high enough to create a shadow were not identified as dunes, although dune building could have been in an incipient stage. Fences along the entire width of the dune between the backshore and the houses were identified. Dune width was not measured because the video was taken at an oblique angle and the scale was uncertain. Fences were revealed as linear, narrow, dark features. The fence at the seaward base of the dune where the beach ends and the dune begins is termed the dune toe fence. The fence on the landward side of the dune, or backdune fence, could not always be identified because the shadow obscured the details.

Fence deployment is rarely documented either in municipal preconstruction or postconstruction reports. Accordingly we had to rely on personal interviews to identify the reasons for deploying fences and their specific locations and configurations. Phone interviews with municipal officers in all 29 municipalities were conducted to identify the rationale for specific fence locations and configurations. Two-thirds of the responses were obtained from officials involved with fence deployment in the Departments of Public Works or Beach and Recreation. Other officials willing to speak with us include former environmental commission members, dune inspectors, and officials who have worked and lived in the municipality for decades. Three of the municipalities never used sand fences, and one municipality provided no information. Questions included (1) purpose of fence deployment, (2) when and where fences are built, (3) configuration of fences and rationale, and (4) number of fences built each time.

Comparison of the 2002 video record with field reconnaissance in June 2008 allowed for identification of the way fence configurations and associated landforms and habitats changed over a 6-year period and allowed for identification of the characteristics of shore-perpendicular fences and backdune fences that could not be derived from the video. At least two locations were visited in each municipality. The site visits followed the interviews so that the outcomes of fence construction including unanticipated outcomes could be compared to the rationale identified by municipal managers. Suggestions for alternative fence deployment were based on the analysis of field observations and synthesis of the literature.

Results

Inventory of Fences

Individual fenced segments varied from 32 to 2000 m in alongshore length in 2002. A total of 82% of the shoreline had fences and 72% had dunes. Most municipalities (18) had dunes and fences (Table 2). Dunes are frequently isolated from each other by pathways at backbeach elevation. Portions of shoreline with dunes but no conspicuous fences may have had dunes that were bulldozed or created by fences and subsequently buried. Straight fences occurred in at least a portion of all but one of the municipalities with fences. Many different configurations were found seaward of boardwalks on the backshore. Single and double fence rows predominate (Table 2). The maximum number of fence rows seen on the video was six, not counting any backdune fence.

It is more common for adjacent municipalities to have dissimilar (16) than similar (12) fence usage and distribution (e.g., fence vs. no fence, fence with no dune vs. no fence or dune, zigzag vs. straight fence). The greatest similarity is in the northernmost municipalities, where no dunes and single, straight fences predominate and create the least topographically diverse landscape.

Table 2 Inventory of shoreline and fence characteristics in municipally managed dunes

Characteristic	No. of municipalities	Mean length of shoreline with these characteristics (%)
Along total shoreline length		
Dunes, no fences	11	9
Fences, no dunes	12	15
No dunes, no fences	13	10
Dunes and fences	18	65
Total		100
Of shoreline with fences		
Fence configuration		
Straight fences	28	79
Zigzag fences	5	15
Straight/zigzag	6	5
Straight/diagonal/ perpendicular	4	2
Total		100
No. of rows		
Single	21	35
Double	19	33
Three	14	19
Four	12	11
Five	4	2
Six	2	0.30
Total		100

The mean length of shoreline with each characteristic was calculated by adding the shoreline segments with a specific characteristic and dividing this sum by the entire shoreline length (90.7 km) for characteristics along the total shoreline length, or dividing the sum by the shoreline with fences (74 km)

Rationale for Fence Locations and Configurations

The main stated purpose of installing fences (Table 3) is to create wider dunes for shore protection, followed by the need to keep people off dunes. Preventing inundation of infrastructure is frequently mentioned, especially in municipalities with no dunes. Managers are aware of some of the adverse effects caused by fences (especially loss of views when dunes become too high), but they consider most of them acceptable, given the importance of the primary purpose.

The location where fences are initially placed is usually the dune toe, to create a wider dune, but placing fences on the foreslope of an existing dune landward of the dune toe fence to create a higher dune or placing them 2–3 m seaward of a boardwalk to prevent inundation was mentioned several times. Fences are deployed when they are perceived to be needed, often at intervals of 1 year or less. They are installed primarily in the fall to build dunes to protect against wave uprush during winter storms and prevent inundation of cultural features by wind-blown sand or in the spring to repair dunes and fences damaged by winter storms and prepare for control of visitors in the summer.

The fence configuration mentioned most frequently is straight because it requires less fence per shoreline length, can be built quickly, requires fewer people to build it, is easier to clean and to remove the sand that builds up against it on the side used by people, and is easy to repair or to dig out if its removal is required. Zigzag fences are frequently mentioned because they trap sand coming from different directions. The sand trapping function is the overriding reason for constructing this type of fence.

Fences are built as single or double rows (Table 3). Zigzag fences are more commonly used in the beginning

Table 3 Summary table of responses of municipal officers or environmental commission members ($N = 29$)

Purpose of installing fences
Create wider dunes (14), create higher dunes (4), or keep the dune in place (2) for shore protection
Keep people from entering the dunes (9), the beach (2), or private property (1)
Prevent inundation of infrastructure (7)
Keep sand on the beach (1)
Location of fence
Dune toe, for a wider dune (12)
Foreslope, for a higher dune (4)
Seaward of boardwalk, to prevent inundation (5)
Backdune, to prevent inundation (1)
Around the dune, for control of access and for stabilization (4)
Create walkways (2)
Season when installed
Late spring to repair dune (11) or control access (10)
Fall, to build dune (7), keep sand on beach or prevent inundation (5), or control access (3)
Fence configuration related to purpose
Straight
Control access (11)
Dune building (10)
Prevent inundation of infrastructure (7)
Fix dunes (2)
Keep sand on beach (1)
Create walkways (1)
Zigzag
Dune building (9)
No. of fences built at one time
One (13)
One or two (7)

The number of municipalities that answered is in parentheses. Some municipalities gave more than one answer for the same question

stages of dune construction. Double zigzag fence rows deployed at the backshore to initiate dune formation are often followed by placing a single straight fence row at the dune toe to continue building the dune seaward and keep people out of the dune. Straight fences may be used to fix eroded dunes originally built with zigzag fences, resulting in a straight/zigzag configuration. Straight fences are more commonly employed than zigzag fences now that most dunes have been built to heights and widths considered acceptable for shore protection. Some municipalities have not deployed fences recently.

Change of Sand Fence Characteristics Over Several Years

Site visits reveal that five municipalities that had fences with no dunes in 2002 have dunes, one that had fences and no dune has neither fences nor dunes, two that had fences and dunes have no conspicuous fences, seven have more fence rows, three have fewer fence rows because of burial, eight have different fence configurations, and eight have no change in numbers of fence rows or configurations. Backdune fences occur in 11 municipalities, more than would be expected, given responses in the interviews (Table 3). Shore-perpendicular fences are common. Twelve municipalities have fences to control pedestrian access to the beach, and property owners in eight municipalities use shore-perpendicular fences at their private paths to the beach or along cross-shore property lines. Many fences also demarcate property lines alongshore. The only fence configuration seen on the ground in 2008 and not on the video is a double line of shore-parallel straight fences partitioned into rectangular compartments by numerous cross-shore fences placed between them.

The impact of fences in organizing and compartmentalizing space is conspicuous when viewed from the ground as well as from the air. Even damaged and decaying fences provide conspicuous reminders of this compartmentalization.

The numbers, locations, and configurations of sand fences and the dunes they create change through time. Fences may deteriorate, be destroyed by wave uprush, be buried by aeolian accretion, or be repaired, removed, or replaced. The number of fences increases as new ones are built to replace those that are weathered or end up far from the original zone of active sand transport. Some fences are repaired, but there is often no local consistency in where repairs are made. Many fences deployed on the backshore in 2002 are now within dunes as sediment has accumulated around them. The number of fence rows within dunes can range from 8 to 10 between completely buried, partially buried weathered remnants and new fences. Zigzag fences now often only occur within the dunes and are partially or completely buried. Many old fences in the dune remain conspicuous, especially where fences were placed in locations that were already well vegetated and little subsequent burial occurred.

The wooden slat fences revealed in the dune in the video record at Manasquan had been replaced by a symbolic rope fence on the seaward side because local residents thought that sand-trapping fences would build the dune higher and obstruct their views. The municipality asked for, and obtained, a permit from the state to install a sand-trapping fence seaward of the dune toe at the beginning of the winter storm season and remove the fence prior to the summer season and bulldoze the accumulation onto the backshore. This practice mimics the former practice of seasonal dune grading that had been eliminated by state regulations, but it is considered acceptable because a protective foredune now remains landward of the temporary accretion. The overriding concern is the value of the dune as a protection structure. The symbolic fence now serves only to keep people out of the dune and was created by simply removing the wooden slats and attaching a rope to the remaining fence posts.

Fence configurations revealed in the video at Ocean Grove were unusual in their shoreline-oblique orientation and location on the middle of the backshore. These backshore fences and the unvegetated ridges they created are conspicuous human intrusions on the beach.

Discussion

Intended and Unintended Effects of Fence Construction

The main intended effect of sand fences to build protective dunes obscures their great significance in changing habitat characteristics. Artificially creating and maintaining a dune for protection of human facilities against flooding, salt spray, and wind-blown sand also provides protection to landward vegetation, resulting in greater species richness than would be possible in the restricted space available on developed coasts and allowing more natural cross-shore gradients of processes and vegetation types to occur (Nordstrom 2008). The value of fences in creating habitat was not mentioned by a single manager (Table 3), underscoring the emphasis on the utilitarian function of the dune as a protection structure. Despite a high level of development, the value of the natural capital of New Jersey is great (NJDEP 2007). Conserving or restoring the natural values and functions of the shore is becoming increasingly important as more coastline is converted to human use (Breton and Esteban 1995; Dauvin and others 2004; Nordstrom 2008), requiring evaluation of use of fences in these other contexts.

The height of sand fences when initially deployed and the narrow spacing between vertical slats make them effective barriers to control human access and differentiate land use, but because they are effective at trapping sand, they create landforms with shapes related to access corridors that are often oriented across the shore rather than alongshore like natural dune ridges.

The effects of a sand fence change through time as the initial structure becomes integrated into the environment it helps create (Fig. 2). The trapping efficiency of the fence is greatest when it is initially emplaced and decreases as sediment accumulates around it creating a new landform. The effect of the fence as a barrier to faunal movement also diminishes as its height above the surrounding surface decreases and as the fence degrades and wooden slats abrade and break. The effect of the fence as a political statement diminishes as it becomes a less conspicuous

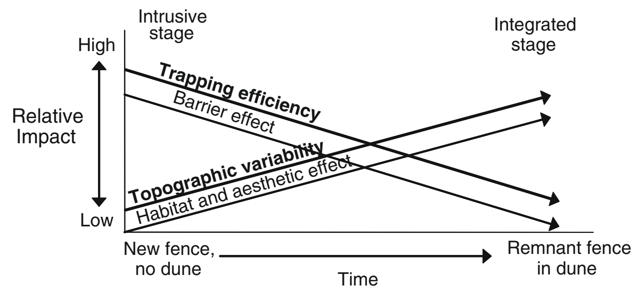

Fig. 2 Diagram of the impact of sand-trapping fences in the coastal zone though time. This scenario may be reinitiated, truncated, or prevented by ongoing human actions

intrusion into the landscape. Accretion caused by the fence increases topographic variability, which creates greater variety of microhabitats. Natural habitat value is also increased as the fence is obscured by subsequent growth of vegetation.

Sand fences can be considered unattractive or attractive, depending on the way they are deployed. A wide range of indicators for assessing the visual image of a landscape exists (Ode and others 2008; Tveit and others 2006), making simple decisions about aesthetic values difficult. Nevertheless, it is difficult to argue that a sand fence newly placed in an environment prized for its natural beauty has positive aesthetic value. The aesthetic value can increase through time as the rationale for fence construction as an aid to natural processes becomes clearer, the size of the exposed parts of the fence decreases, and the remaining components create an element of mystery or nostalgia. These characteristics will improve if the fence is placed in a location where the delivery of sediment is sufficient to bury most of it.

Present Fence Usage and Alternatives to Fence Deployment

Sand fence locations and configurations vary, depending on the management decisions established in each municipality. The method of emplacement of sand fences is often according to the whim of local managers (Nordstrom 2008), despite the existence of technical assessments and guidelines for their use for shore protection (e.g., Coastal Engineering Research Center 1984; Hotta and others 1987, 1991; Ranwell and Boar 1986). The result is a heterogeneous coastal landscape, with fences appearing as conspicuous intrusions and reminders of the artifactual nature of the landforms. The frequency at which new fences are deployed and the changing location of their placement create a highly variable human-influenced topography through both time and space.

Zigzag fences create wider dunes with more undulating crestlines and more gently sloping dune faces than straight alignments, resulting in a closer approximation to the shapes of natural dunes (Snyder and Pinet 1981). This greater compatibility with natural dune forms was not mentioned by managers as a rationale for use of zigzag fences, but it makes them more useful than straight fences for constructing dunes landward of narrow beaches, where sand supply is limited and dunes are not expected to grow beyond the initial ridge. If space for additional rows of fences to accumulate sand exists, straight fences could be used to create the multiple ridges more common to natural dune fields.

Adding rows of fences on the foreslopes of dunes built with fences can create higher dunes with much greater volume and greater value as protection structures (CERC 1984; Mendelssohn and others 1991; Miller and others 2001; Savage and Woodhouse 1968). Dune toe fences are more commonly deployed in the New Jersey dunes than foreslope fences (Table 3), in part because management decisions have strong input from property owners who want lower dunes for views of the water. Placing additional fences on the foreslope or dune toe may be unnecessary in any case. The location of the contact between the foredune and backshore is determined by erosion of the foredune during storms and dune accretion following storms. Storm wave uprush may eliminate the seaward portion of the dune and create an erosional scarp, but poststorm deposition on the beach creates a new source of sand to be blown to the foredune, reestablishing the dune sediment budget. Once established, the dune form and the vegetation on it can become the obstacles that trap sand (Nordstrom and others 2000). Adding sand fences on the seaward side of a dune that can function as a barrier to transport onshore has little value from the standpoint of shore protection. Sand fences tend to create steep dune faces that are incompatible with plover nesting (Melvin and others 1992), providing an additional reason to restrict the use of sand fences on the seaward side.

Human structures can be visually acceptable in landscapes if they are in harmony with natural features (Kearney and others 2008). Sand fences will not represent the best practice in environmental management or communicate good environmental goals if they are used out of context. In some cases, they do not serve as proper guides for controlling human traffic, nor are the linear overstabilized landforms they create examples of the kinds of dynamic nature that can be achieved in the state. Fences and walls, like other boundaries (Newman and Paasi 1998), can have significance as metaphors (Cohen 2006), but the messages to managers and users of the landscape must be clear to have value in this context. The purposes of some configurations, such as straight/diagonal/perpendicular fences and isolated fenced enclaves on the backshore, are unclear to beach users, providing little insight into the relationship between management actions and use of the backshore and dune environments.

The coast is an important geographical symbol and a landscape that manifests communal ideals of inclusiveness and belonging (Davidson and Entrikin 2005). Human structures should reinforce these attributes to the extent possible. Sand-trapping fences used for controlling access in locations sheltered from the wind or in locations where the amount of sand in transport is insufficient to generate new landforms will remain visually intrusive and function as psychological barriers and impediments to faunal movement. Those constructed on or near the beach often create unnatural shore-normal shapes and extend seaward of the normal dune toe. There appears to be little advantage in using sand-trapping fences over symbolic fences for controlling pedestrian access. The replacement of slat fences with wooden post and rail and rope fences represents an effective way of separating the incompatible sand trapping and crowd control functions. These fences convey the message that the dune is a protected environment but do not exclude that environment from the visual landscape the way sand-trapping fences do. Post-and-rail and rope fences are not barriers to fauna and are less visually intrusive than sand fences. Rope fences are more easily constructed, more expendable, easy to replace if damaged, and less intrusive than sand fences and are better placed on the more dynamic and more naturally functioning seaward side. Wooden rail fences are better placed on the landward side of the dune, which is less dynamic. This type of fence was almost universally adopted by settlers in timbered parts of the United States in the past (Martin 1888) and is more appropriate closer to human structures, where historic and nostalgic considerations may be more important.

Conclusion

The temporal and spatial characteristics of sand fences help define the coastal landscape and communicate the history of management goals and priorities, which presently are not based on restoring a natural image or function. Decisions for fence deployment made at the municipal level result in considerable longshore variety in numbers and configurations of fences and the landforms they create. Sand fences may have to be accepted as necessary human adjustments to developed coasts because of their value in creating dunes to provide protection against coastal hazards, but use of fences can be made more compatible with natural processes and biota. Sand fences impede movement of fauna and are physically and psychologically exclusionary. These detrimental aspects worsen with overuse of fences. New fences or fences placed in locations where little sand can be trapped are conspicuous. More careful consideration should be given to the initial placement of sand fences where regulations prevent their removal. They should not be placed where a dune of adequate size already exists, where they would trap sand in unnatural configurations, or where they cannot be buried, such as in vegetated portions of the dune or on narrow beaches where sources of wind blown sand are restricted. Symbolic fences that are less expensive or less visually intrusive and allow for free movement of biota should be used for controlling pedestrian access. Many of these suggestions are not based on controlled experiments, and some may need to be tested before being implemented as formal guidelines. It is necessary to conduct studies that provide a scientific rationale and design principles for helping municipal managers select fencing alternatives that allow for evolution of dunes as sustainable landforms that can provide a greater suite of ecosystem services. The rationale for use of fences, current guidelines, and methods of communicating them to local managers need to be explored, updated and expanded to better preserve or restore dune functions and services and allow dunes to become more than shore protection structures.

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